W/Z PRODUCTION CROSS SECTIONS AND ASYMMETRIES AT E$_{CM}$ = 2TEV

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The most recent results for W and Z boson production cross sections and asymmetries are presented from the CDF and DØ collaborations using Run II data taken at the Fermi National Accelerator Laboratory (FNAL) Tevatron. Data set sizes range from $72pb^{-1}$to $226pb^{-1}$, and results range from published to preliminary. Results presented agree with the Standard Model and world averages within errors.

1 Motivation

Decays of W and Z bosons into leptons provide some of the cleanest and simplest processes with which to study electroweak interactions in the Standard Model (SM). They provide: data with which one can gain a better understanding of the resolutions and efficiencies of one's detector and triggers; cross sections to which other processes can be normalized; and experimental tests of the validity of some SM parameters.

2 DØ and CDF Detectors and Analysis Methods

CDF and DØ are experiments studying proton-antiproton collisions at a center of mass energy (E_{CM}) of $1.96TeV$ ("Run II"). Both detectors have a cylindrical geometry around a proton-antiproton interaction region, and both have undergone extensive upgrades since Run I data was collected at E_{CM} of $1.8TeV$. Upgrade details have been published[1].

These analyses focus on lepton decay channels. The Z boson events are required to have two energetic leptons. The W boson events are required to have one energetic lepton, and missing transverse energy ($\not\!\!E_T$) as evidence of the undetected neutrino. The majority of the backgrounds are from QCD processes, with levels estimated using QCD dijet data. Main systematic

uncertainties are from parton distribution functions (PDFs) (1-2%). Luminosity measurement uncertainties are about 6%, and are not considered as part of the other systematic uncertainties.

Electrons are required to have an isolated electromagnetic (EM) calorimeter cluster with a matching track. For muons, an isolated track is required that matches to an isolated calorimeter MIP or muon system track segment, and an appropriate timing coincidence and impact parameter are required. For the tau channel, one or three isolated tracks plus a narrow jet and reconstructible neutral pions are required. Hadronic decay products that reconstruct to the tau mass are preferred through cuts or neural network parameters.

3 Z Boson Cross Sections

3.1 $Z \to ee$ Cross Section

To select $Z \to ee$ events, both experiments require two EM objects with transverse energies (E_T) greater than $25GeV$. The pseudorapidity (η) range selected by CDF for this study goes out to ± 2.8, which includes both the central and plug calorimeters. The results from DØ have an η range of ± 1.05, which includes only the central calorimeter. The largest background (about 2%) comes from QCD dijet events. Dominant systematic uncertainties for this decay channel come from PDFs and electron identification, each at about 1.5%.

DØ has released preliminary results for a $177pb^{-1}$data set[2], and the resulting cross section is given in (1). The two electron invariant mass for this data set is shown in Fig. 1. CDF has published results for $72pb^{-1}$of data[3], and the resulting cross section is given in (2).

$$\text{DØ} : \sigma \times \mathcal{B}(Z \to ee\,) \; = \; 264.9 \pm 3.9_{stat} \pm 9.9_{sys} \pm 17.2_{lum}\, pb \tag{1}$$

$$CDF : \sigma \times \mathcal{B}(Z \to ee\,) \; = \; 255.8 \pm 3.9_{stat} \pm 5.5_{sys} \pm 15_{lum}\, pb \tag{2}$$

3.2 $Z \to \mu\mu$ Cross Section

$Z \to \mu\mu$ events are selected by requiring two muon objects with a minimum transverse momentum (p_T). For DØ the cut was $p_T > 15GeV/c$ and for CDF the cut was $p_T > 20GeV/c$. Backgrounds are at the 1% level and include QCD events and $Z \to \tau\tau$ decays. The largest systematic uncertainties for DØ come from PDFs and a Drell-Yan correction, each at about 1.5%. The CDF analysis does not apply a Drell-Yan correction, but does include PDF uncertainties.

Both the DØ and the CDF most recent results for this decay channel are preliminary, using data sets of $148pb^{-1}$and $194pb^{-1}$, respectively[5,6]. The cross sections are given in (3) and (4) and plots of the invariant two-muon reconstructed mass are shown in Figs. 2 and 3.

$$\text{DØ} : \sigma \times \mathcal{B}(Z \to \mu\mu\,) \; = \; 291.3 \pm 3.0_{stat} \pm 6.9_{sys} \pm 18.9_{lum}\, pb \tag{3}$$

$$CDF : \sigma \times \mathcal{B}(p\overline{p} \to Z/\gamma^{*} \to \mu\mu\,) \; = \; 253.1 \pm 4.2_{stat}({}^{+8.3}_{-6.4})_{sys} \pm 15.2_{lum} pb \tag{4}$$

3.3 $Z \to \tau\tau$ Cross Section

To distinguish taus from other leptons, both CDF and DØ require that one tau decay leptonically (into $e\nu_e\nu_\tau$ or $\mu\nu_\mu\nu_\tau$), and the other decay hadronically (into (1 or 3)$\pi^{\pm}\nu_\tau$ + $N\pi^0$) for $Z \to \tau\tau$ events. DØ also requires that the taus have opposite charges. The largest backgrounds for this decay channel are dijet events (about 10%) and other leptonic Z decays (about 6%).

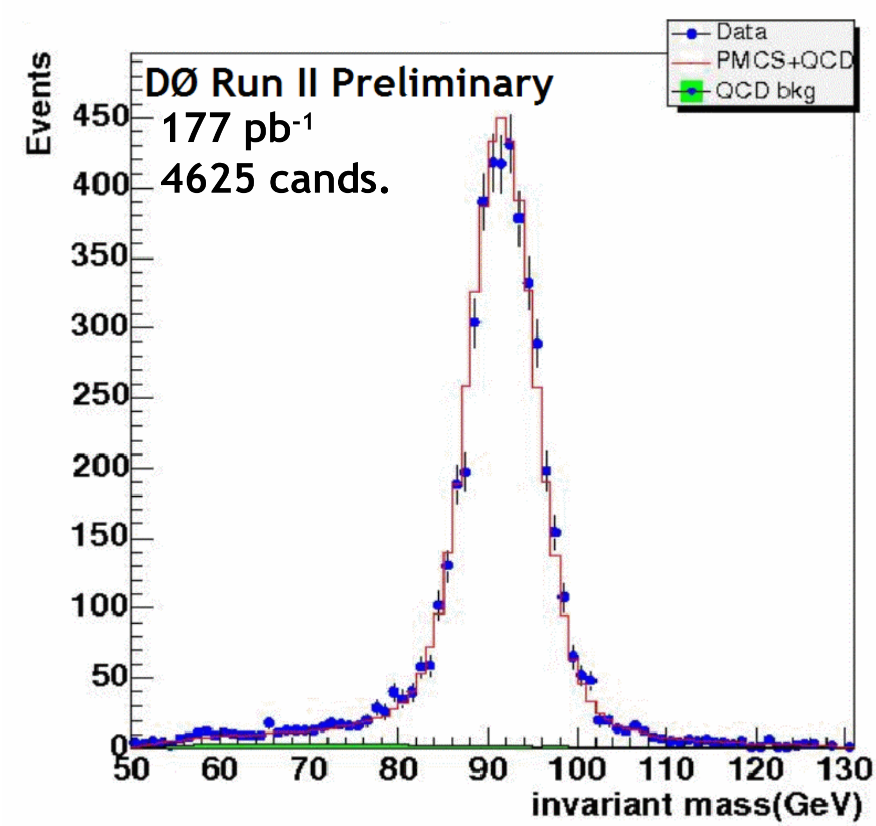

Figure 1: The two electron invariant mass of $Z \to ee$ events from $177pb^{-1}$of DØ data[2], with $|\eta| < 1.05$.

Cross sections for $Z \to \tau\tau$ are given in (5) and (6) for $226pb^{-1}$ and $72pb^{-1}$ of data, respectively. Details are available in publications for both DØ[7] and CDF[8]. Leptonic Z cross section results are compared in Fig. 4.

$$\text{DØ} : \sigma \times \mathcal{B}(Z \to \tau\tau) = 237 \pm 15_{stat} \pm 18_{sys} \pm 15_{lum} pb \tag{5}$$
$$CDF : \sigma \times \mathcal{B}(p\bar{p} \to Z/\gamma^* \to \tau\tau) = 242 \pm 48_{stat} \pm 26 sys \pm 15_{lum} pb \tag{6}$$

4 W Boson Cross Sections

4.1 $W \to e\nu$ Cross Section

To identify $W \to e\nu$ decays, both experiments required an electron with E_T greater than $25GeV$ that matched to a track. DØ loosened this requirement to $20GeV$ for electrons in the central region of their detector. $\not{E}_T$ of more than $25GeV$ is also required. The most significant backgrounds are QCD dijet events and $Z \to ee$ events at about 2% each. The largest uncertainties come from PDFs and electron identification at about 1.5% each.

CDF has results for a $72pb^{-1}$data set[3] that gives the cross section in (7) for the central part of their detector. DØ finds the cross section given in (8) for $177pb^{-1}$of data[2].

$$CDF : \sigma \times \mathcal{B}(W \to e\nu) = 2780 \pm 14_{stat} \pm 60_{sys} \pm 166_{lum} pb \tag{7}$$
$$\text{DØ} : \sigma \times \mathcal{B}(W \to e\nu) = 2865 \pm 8.3_{stat} \pm 76_{sys} \pm 186_{lum} pb \tag{8}$$

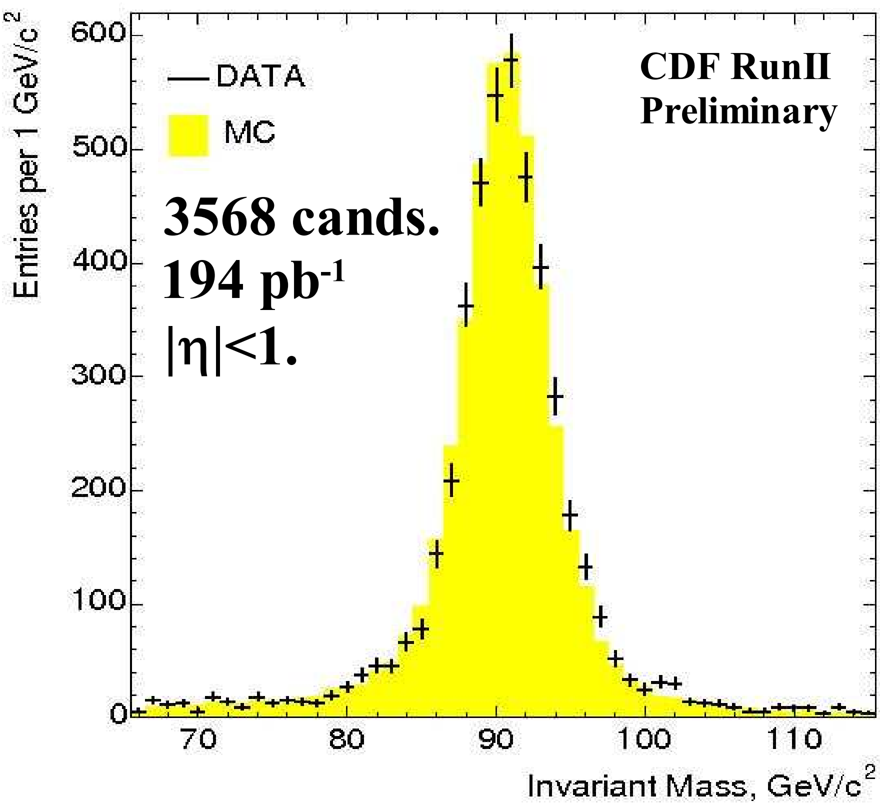

Figure 2: The two muon invariant mass of $Z \to \mu\mu$ events from $194pb^{-1}$of CDF data[6], with $|\eta| < 1$.

4.2 $W \to \mu\nu$ Cross Section

DØ and CDF both require $W \to \mu\nu$ events to have a muon track with p_T greater than $20GeV$ and $\not{E}_T$ greater than $20GeV$. The largest backgrounds come from similar types of decays ($Z \to \mu\mu$ and $W \to \tau\nu$ at about 6%), and from QCD b-jets (about 1% as calculated from data). The largest systematic uncertainties come from efficiencies (about 1.5%) and PDFs (about 1%).

CDF has a result for $194pb^{-1}$of data[6] that results in the cross section given in (9). DØ has a preliminary cross section given in (10) for $96pb^{-1}$of data[10].

$$CDF : \sigma \times \mathcal{B}(W \to \mu\nu\,) \;=\; 2786 \pm 12_{stat} \pm (^{+65}_{-55})_{sys} \pm 166_{lum} pb \qquad (9)$$

$$\text{DØ} : \sigma \times \mathcal{B}(W \to \mu\nu\,) \;=\; 2989 \pm 15_{stat} \pm 81_{sys} \pm 194_{lum} pb \qquad (10)$$

4.3 $W \to \tau\nu$ Cross Section

To identify $W \to \tau\nu$ events, CDF requires the E_T of the tau to be greater than $25GeV$ and a corresponding $\not{E}_T$ of $25GeV$. The largest uncertainty is from tau identification at about 6% and the largest backgrounds are from QCD dijets (about 15%) and $W \to e\nu$ decays (about 4%). The cross section calculated from $72pb^{-1}$of data[8] is given in (11). Leptonic W cross section results are compared in Fig. 6. DØ is working on the $W \to \tau\nu$ cross section for Run II data.

$$CDF : \sigma \times \mathcal{B}(W \to \tau\nu\,) \;=\; 2620 \pm 70_{stat} \pm 210_{sys} \pm 160_{lum} pb \qquad (11)$$

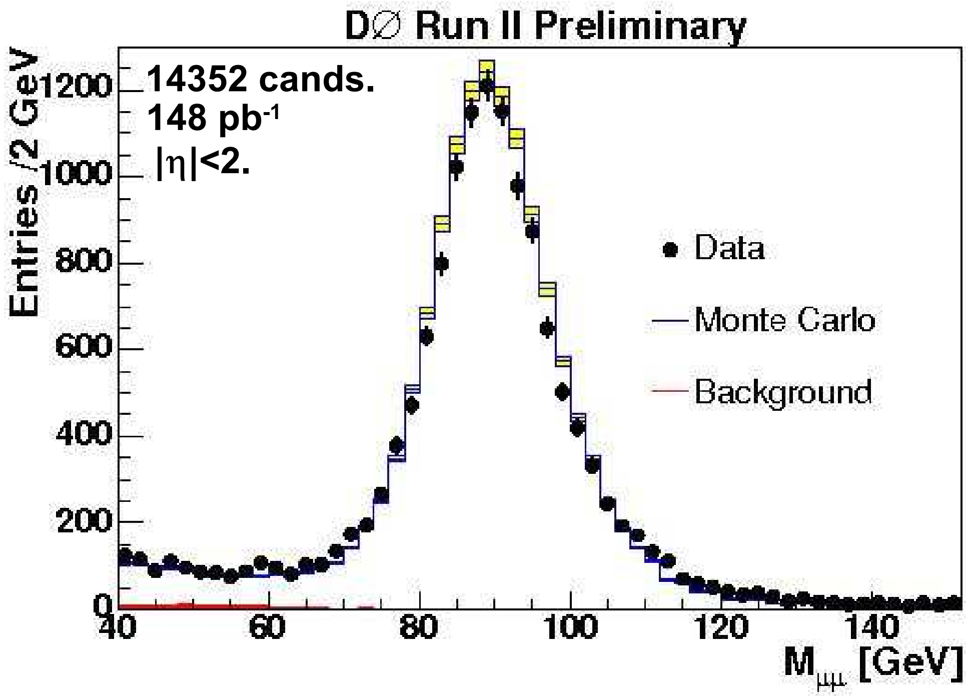

Figure 3: The two muon invariant mass of $Z \to \mu\mu$ events from $148pb^{-1}$of DØ data[5], with $|\eta| < 2$.

5 Drell-Yan+Z forward/backward Asymmetry

One can further test SM predictions by looking at the difference in lepton production in the proton direction verses that in the antiproton direction. The SM vector and axial-vector couplings of quarks and leptons to Z bosons and virtual photons predicts an asymmetry in the forward and backward cross sections (A_{fb}) of the process $q\overline{q} \to Z/\gamma^* \to ee$ versus the two electron invariant mass. See CDF's published article for the Drell-Yan+Z A_{fb} analysis of their $72pb^{-1}$data set[11]. DØ has recently approved the analysis of $177pb^{-1}$of data[12], and their A_{fb} result is shown in Fig. 7.

6 W Charge Asymmetry

By improving PDFs, systematic uncertainties can be reduced. The u quark of the proton carries a higher fraction of the particle's momentum than the d quark, resulting in W^+s being boosted in the proton direction at hadron colliders. Measuring the resulting W charge asymmetry can be used to improve the u and d PDFs. CDF has a new result for $170pb^{-1}$of data[13]. Plots of asymmetry versus pseudorapidity for several transverse energy ranges are shown in Fig. 8.

7 Summary

All results presented agree with SM predictions within errors. These results also show the DØ and CDF collaborations are making good progress in measuring electroweak parameter values, gaining better understanding of their detectors and laying the groundwork necessary for more complex analyses.

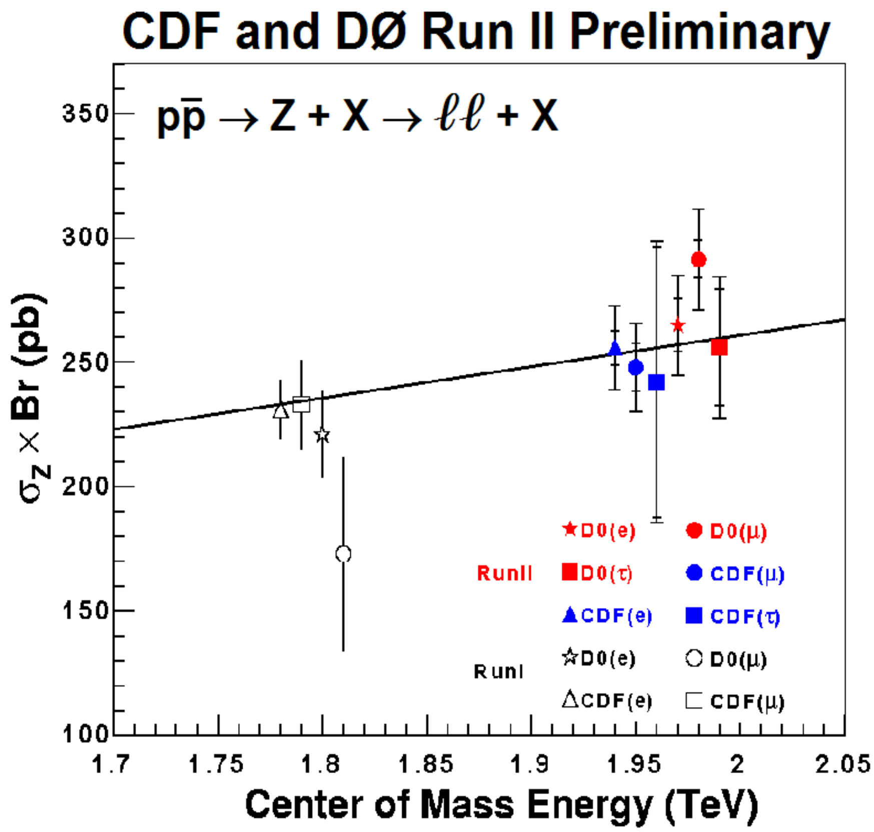

Figure 4: Summary of Z boson cross section measurements[9] from CDF and DØ. Data was taken at $1.8 TeV$ or $1.96 TeV$ - points are spread for ease of reading. The line is a Standard Model prediction[4].

References

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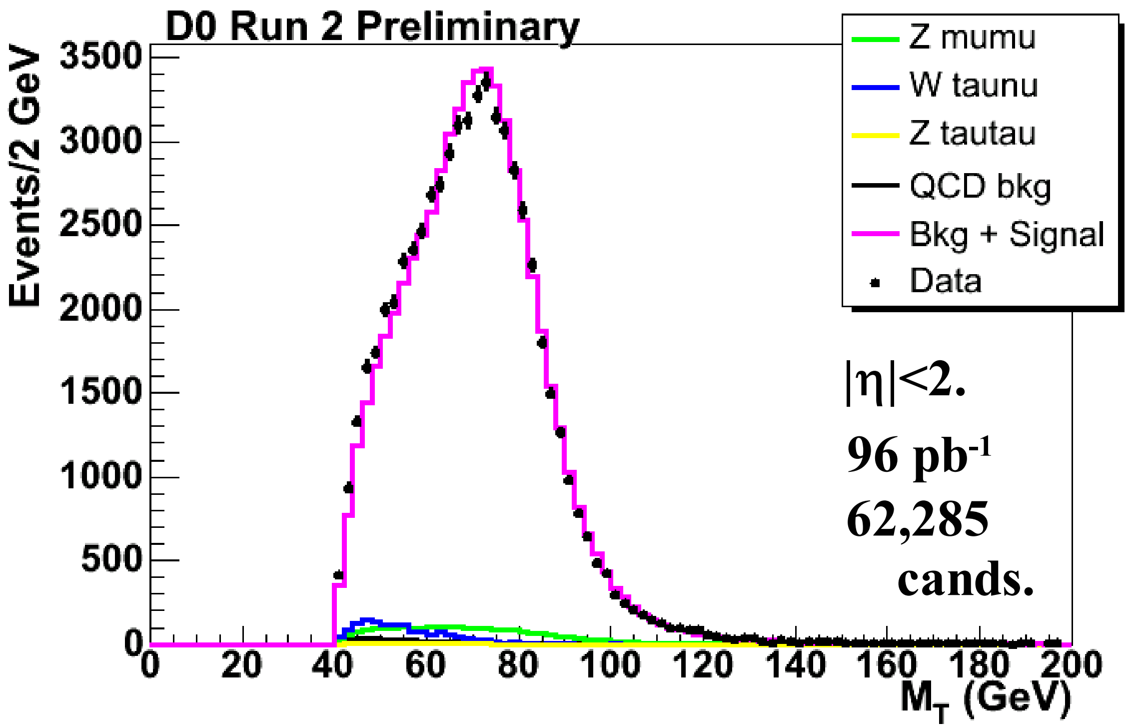

Figure 5: The transverse mass of $W \to \mu\nu$ events from $96pb^{-1}$of DØ data[10], with $|\eta| < 2$.

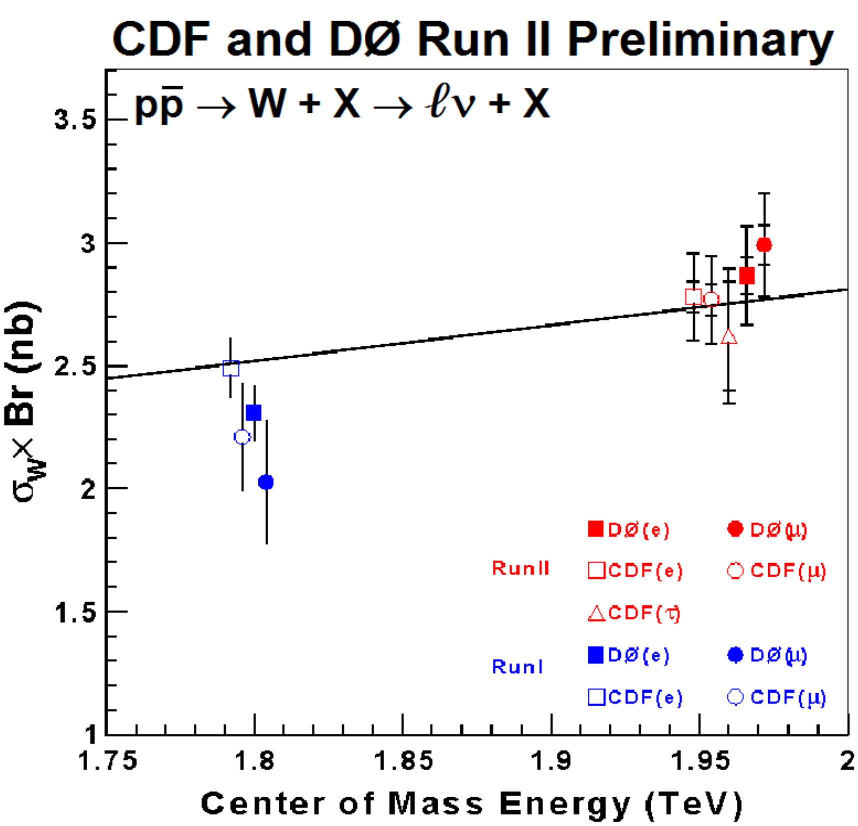

Figure 6: Summary of W boson cross section measurements[10] from DØ and CDF. Data was taken at $1.8TeV$ or $1.96TeV$ - points are spread for ease of reading. The line is a Standard Model prediction[4].

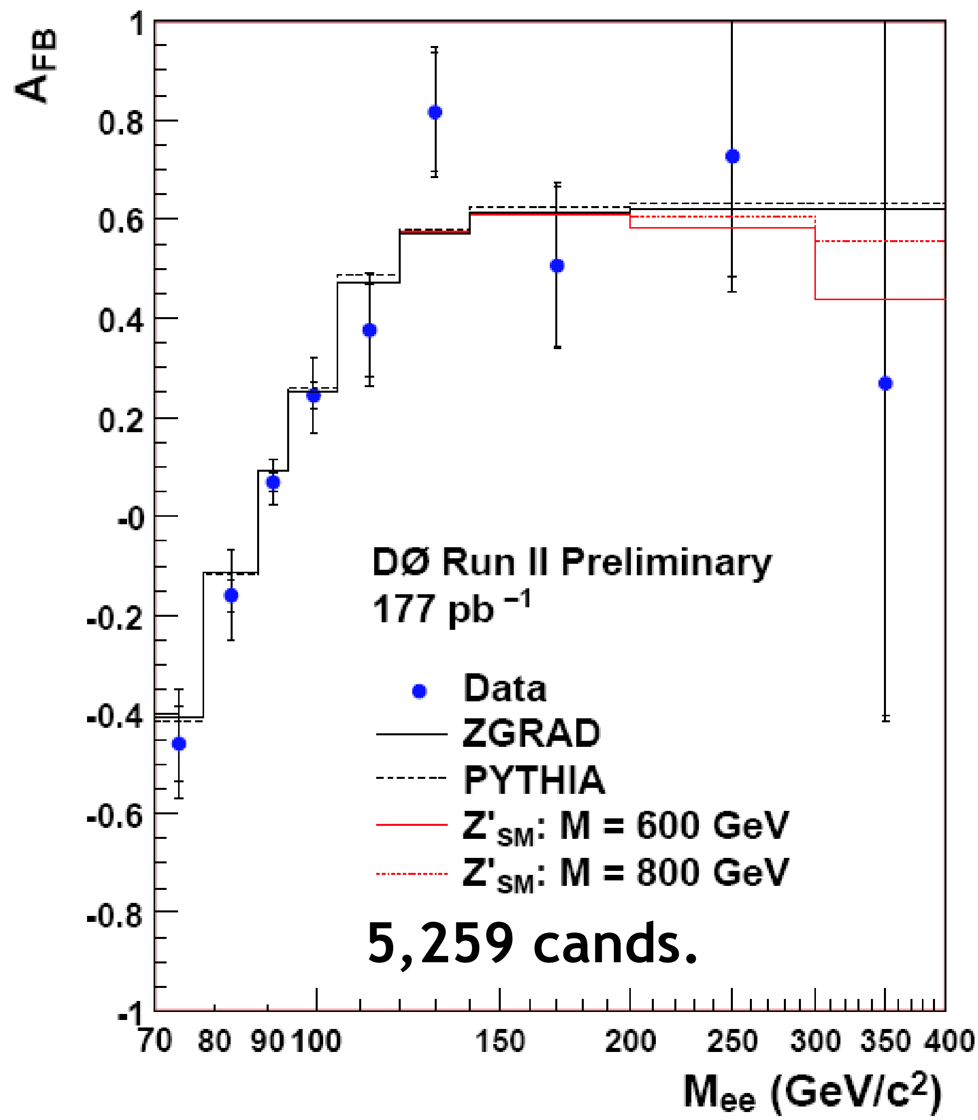

Figure 7: The $Z \to ee$ forward-backward asymmetry in $177pb^{-1}$ of DØ Run II data[12].

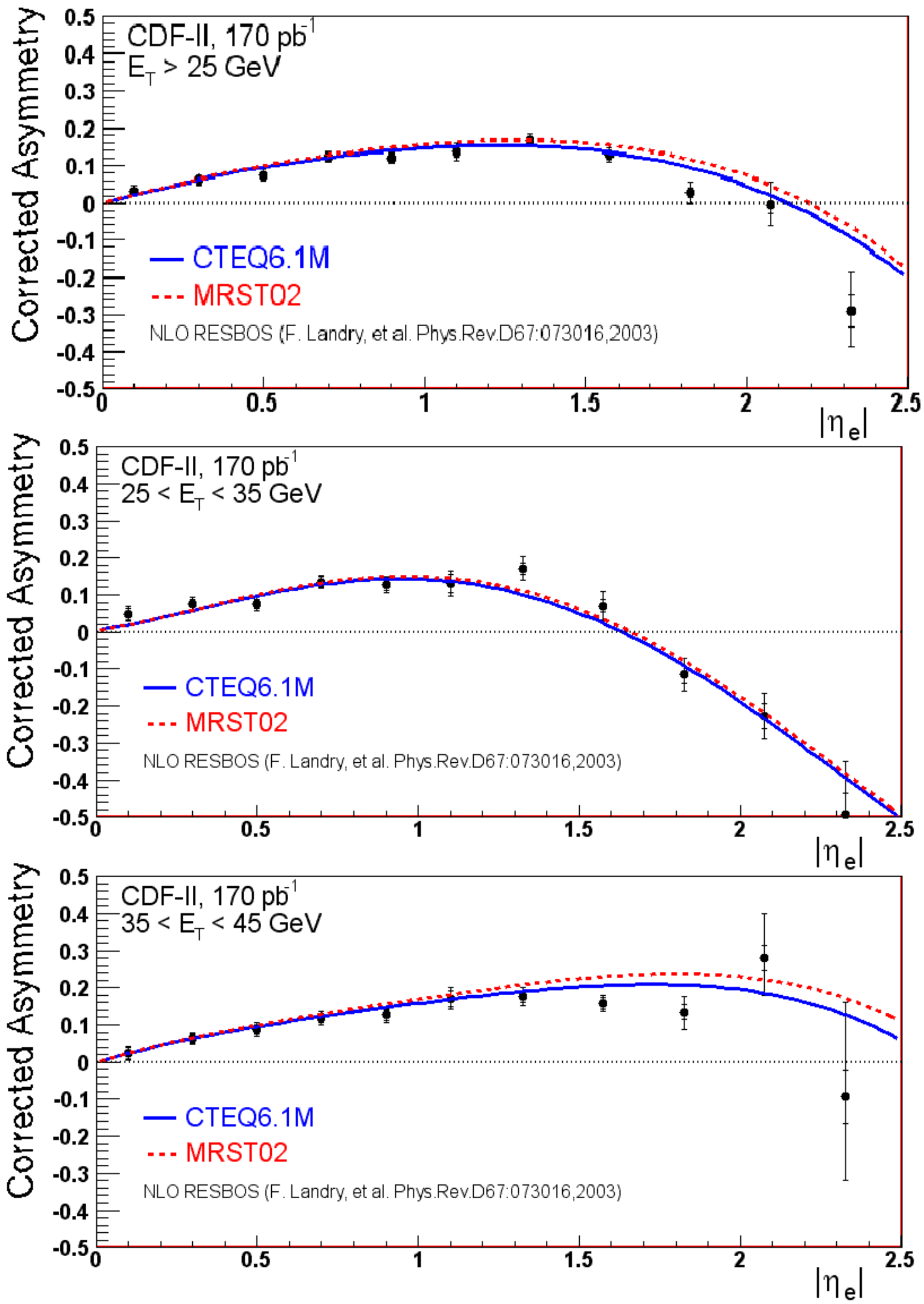

Figure 8: The W charge asymmetry in $170pb^{-1}$ of CDF Run II data[13], broken down by E_T range.